

## **Section III**

### **Academic References**

Yunus A. Cengel, Heat Transfer: A Practical Approach, 1998.

David S. Steinberg, Cooling Techniques for Electronic Equipment, 1991.

# *Cooling Techniques for Electronic Equipment*

Second Edition

Dave S. Steinberg

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John Wiley & Sons, Inc.

NEW YORK / CHICHESTER / BRISBANE / TORONTO / SINGAPORE

that larger pumps and fans and more power be used to overcome the added resistance.

## 6.2 COOLING AIRFLOW DIRECTION FOR FANS

When a fan is used for cooling electronic equipment, the airflow direction can be quite important. The fan can be used to draw air through a box or to blow air through a box. A blowing fan system will raise the internal air pressure within the box, which will help to keep dust and dirt out of a box that is not well sealed. A blowing system will also produce slightly more turbulence, which will improve the heat transfer characteristics within the box. However, when an axial flow fan is used in a blowing system, the air may be forced to pass over the hot fan motor, which will tend to heat the air as it enters the electronic box, as shown in Figure 6.1.

An exhaust fan system, which draws air through an electronic box, will reduce the internal air pressure within the box. If the box is located in a dusty or dirty area, the dust and dirt will be pulled into the box through all of the small air gaps if the box is not sealed. In an exhaust system, the cooling air passes through an axial flow fan as the air exits from the box, as shown in Figure 6.2. The cooling air entering the electronic box is therefore cooler.

The position of the fan blades within an axial flow fan housing can be a critical factor in determining how well a fan will perform. This is especially important in high-speed fans that have speeds greater than about 8000 rpm.

An examination of most high-speed axial flow fans will show that the fan blades are not located at the center of the tubular housing but near one end. When the fan is located adjacent to a restricted area, such as a 90° bend, the fan blades should be positioned so that they are at the downstream end of the housing, for the best performance. Air has weight and kinetic energy, so that the air velocity must be allowed to develop to effectively overcome the flow resistance. When the fan blades

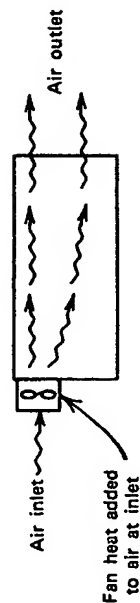


Figure 6.1 Axial flow fan blowing cooling air through a box.

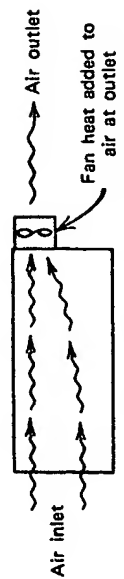


Figure 6.2 Axial flow fan drawing cooling air through a box.

## 6.2 COOLING AIRFLOW DIRECTION FOR FANS

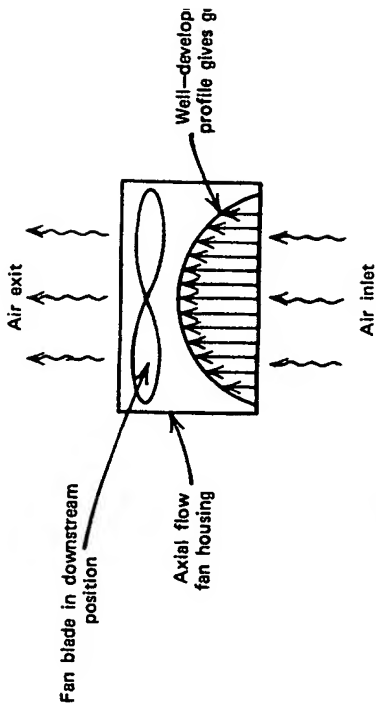


Figure 6.3 Well-developed velocity profile in an axial flow fan

are located at the downstream end of the fan housing, the air has a short flow path. This improves the velocity profile, as shown in Figures 6.3 and 6.4.

It makes no difference if a blowing or an exhaust fan system is used. The reduced flow efficiency for the fan shown in Figure 6.4 will not be a casual observer. When the fan is in operation, you can place your hand at the exhaust and feel a large volume of air flowing through the fan. If the fan is being short-circuited. The airflow at the outer perimeter of the fan housing is slowly passed across the fan exhaust, it will be moving away from the fan, but the airflow at the center will be moving toward the fan, resulting in a short circuit, as shown in Figure 6.5.

Some good fan installations and some poor ones are shown in Figure 6.6. On these types of installations have shown that the cooling airflow more than doubled just by properly orienting the position of the fan in the fan housing when the fan is located adjacent to an area that restricts the flow of cooling air.

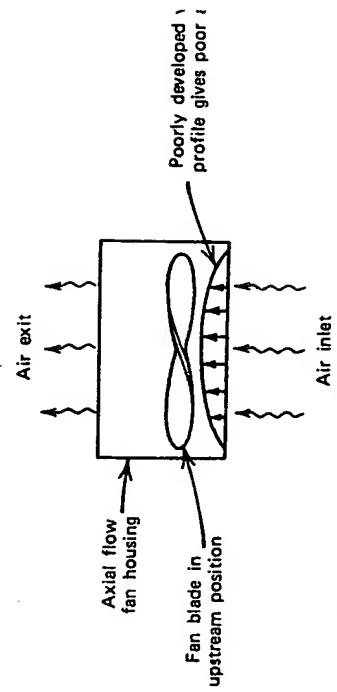


Figure 6.4 Poorly developed velocity profile in an axial flow fan

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## 6.28 DIRECT AIR IMPINGEMENT COOLING

The standard method for cooling large racks and cabinets has been to provide a blower at the bottom of the cabinet that blows cooling air upward through large vertically oriented plug-in PCBs spaced slightly more than 1 in apart. The PCB spacing will depend upon the height of the electronic components. The PCBs form ducts that guide the cooling air to the top of the cabinet where the air is exhausted, as shown in Figure 6.47.

The problem with this cooling method is that the air at the top of the cabinet is much hotter than the air at the bottom of the cabinet, because the air picks up heat as it passes over the PCBs and the hot components. In addition, where large components are upstream from small components, the cooling airflow may be blocked so the small components are not cooled properly. These types of problems can often be avoided by using a direct cooling air impingement method for removing the heat from the electronic assembly [54, 55].

The direct air impingement cooling method works best on PCBs that utilize high-power-dissipating pin grid arrays (PGAs) and DIPs. The standard cabinet cooling arrangement can still be used where the blower is mounted at the base of the cabinet, with the cooling air directed upward toward the vertically oriented PCBs. At this point the systems change. In the direct air impingement method, the cooling air is directed into a flat, slim plenum that is immediately adjacent and parallel to each PCB. The plenum has special openings and orifices located directly opposite the high-heat-dissipating components on the plug-in PCBs, which forces

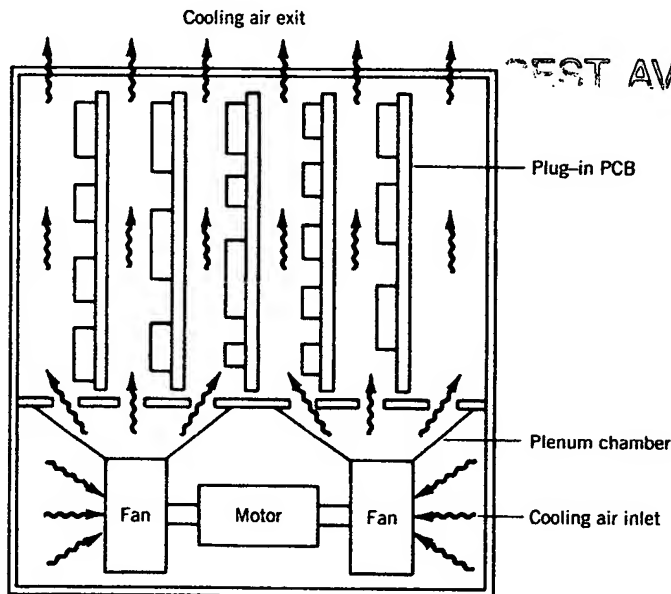


Figure 6.47 Standard cooling system for a large cabinet.

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# HEAT TRANSFER

## A PRACTICAL APPROACH

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Air Cooling: Forced Convection

otted against the flow rate of air. Note that a fan creates the *highest* pressure head at *zero* flow rate. This corresponds to the limiting case of blocked exit vents of the enclosure. The flow rate increases with decreasing static head and reaches its maximum value when the fan meets no flow resistance.

Any electronic enclosure will offer some resistance to flow. The system resistance curve is *parabolic* in shape, and the pressure or head loss due to this resistance is nearly proportional to the *square* of the flow rate. The fan must overcome this resistance to maintain flow through the enclosure. The design of a forced convection cooling system requires the determination of the total system resistance characteristic curve. This curve can be generated accurately by measuring the static pressure drop at different flow rates. It can also be determined approximately by evaluating the pressure drops.

A fan will operate at the *point* where the fan static head curve and the system resistance curve *intersect*. Note that a fan will deliver a higher flow rate to a system with a low flow resistance. The required airflow rate for a system can be determined from heat transfer requirements alone, using the design heat load of the system and the allowable temperature rise of air. When the flow resistance of the system at this flow rate can be determined analytically or experimentally. Knowing the flow rate and the needed pressure head, it is easy to select a fan from manufacturers' catalogs that will meet both of these requirements.

Below we present some general guidelines associated with the forced-air cooling of electronic systems.

Before deciding on forced-air cooling, check to see if *natural convection* cooling is adequate. If it is, which may be the case for low-power systems, incorporate it and avoid all the problems associated with fans such as cost, power consumption, noise, complexity, maintenance, and possible failure.

Select a fan that is neither too small nor too large. An *undersized* fan may cause the electronic system to overheat and fail. An *oversized* fan will definitely provide adequate cooling, but it will needlessly be larger and more expensive and will consume more power.

If the temperature rise of air due to the power consumed by the motor of the fan is acceptable, mount the fan at the *inlet* of the box to pressurize the box and filter the air to keep dirt and dust out (Fig. 14-48).

Position and size the air exit vents so that there is *adequate airflow* throughout the entire box. More air can be directed to a certain area by enlarging the size of the vent at that area. The total exit areas should be at least as large as the inlet flow area to avoid the choking of the airflow, which may result in a reduced airflow rate.

Place the most critical electronic components near the *entrance*, where the air is coolest. Place the components that consume a lot of power near the exit (Fig. 14-49).

Arrange the circuit boards and the electronic components in the box such that the *resistance* of the box to airflow is *minimized* and thus the flow rate of

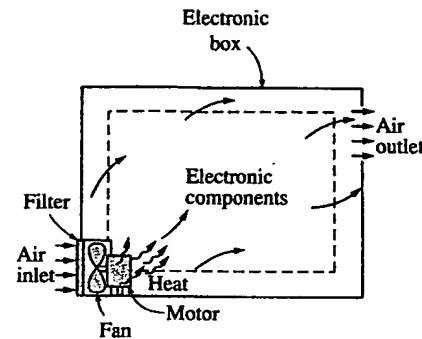


FIGURE 14-48

Installing the fan at the inlet keeps the dirt and dust out, but the heat generated by the fan motor in.

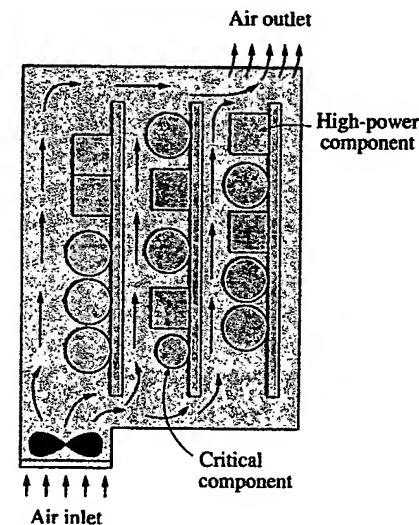


FIGURE 14-49

Sensitive components should be located near the inlet and high-power components near the exit.

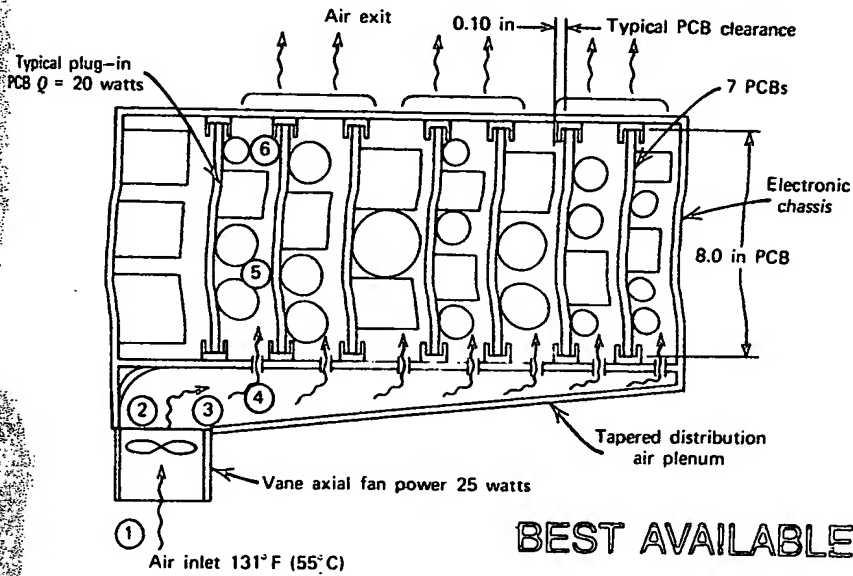


Figure 6.13 Plan view of fan-cooled electronic box.

required. The preliminary analysis can also be used to establish an approximate fan size.

The maximum allowable temperature rise from the air inlet to the component surface hot spot temperature is  $212^{\circ}\text{F} - 131^{\circ}\text{F} = 81^{\circ}\text{F}$  ( $100^{\circ}\text{C} - 55^{\circ}\text{C} = 45^{\circ}\text{C}$ ). There are two major contributors to this temperature rise.

- 1  $\Delta t$  due to the heat input from the fan and the electronics to the cooling air.
- 2  $\Delta t$  due to the thermal resistance across the convection film from the cooling air to the surface of the component.

These temperature rise sources can be examined in more detail to see how much each contributes to the total value.

#### $\Delta t$ due to the Heat Input from the Fan and the Electronics to the Cooling Air

Heat generated by the fan motor is usually removed by convection from the cooling air. If the fan is bolted to a large heat sink away from the electronic box, a large part of the heat from the fan motor may be removed by direct conduction and radiation from the fan housing to the heat sink.

When the fan is bolted directly to the chassis that houses the electronics, the chassis walls may be quite hot, so relatively little fan heat may be transferred to the chassis. Therefore, it is a good practice to be slightly conservative and to assume that all of the fan power will be picked up by the cooling air as it passes through the fan and into the chassis housing.